Age-related trends in utilization and outcome of open and endovascular repair for abdominal aortic aneurysm in the United States, 2001-2006

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Objective: **This study used a large national administrative in-hospital database to compare utilization and age-specific outcomes between open repair (OAR) and endovascular (EVAR) repair for the treatment of abdominal aortic aneurysm (AAA).**

Methods: **Discharges with the principal International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes for EVAR and OAR and principal diagnosis code of intact AAAs were selected from the 2001 to 2006 Nationwide Inpatient Sample (NIS). Weighted least-square regression was used to test the trend of utilization by age. Multiple linear and logistic regression analyses were used to assess the risk-adjusted outcomes.**

Results: **Nationally, the estimated number of elective AAAs treated with EVAR increased from 11,171 in 2001 to 21,725 in 2006 ($P = .003$). The number of elective AAAs treated with OAR declined from 17,784 to 8451 during the same period ($P < .001$). By 2006, EVAR was more frequently used than OAR for patients of all ages. Compared with the younger age groups, patients aged ≥85 years had a significant increase in the total number of asymptomatic AAA repairs, driven almost entirely by an increase in the use of EVAR. Compared with open patients, EVAR patients had a significantly shorter length of hospitalization (adjusted mean, 2.99 days [95% confidence interval (CI), 2.97-3.01] vs 8.78 days [95% CI, 8.53-8.57]), less in-hospital mortality (odds ratio [OR], 0.23; 95% CI, 0.19-0.28), fewer in-hospital complications (OR, 0.27; 95% CI, 0.25-0.28), and a higher likelihood of being discharged to home (OR, 3.95; 95% CI, 3.62-4.31). The reduction of complications from the use of EVAR versus OAR was most dramatic for the oldest patients.**

Conclusions: **As short-term surgical outcomes are consistently improving for patients undergoing AAA repair, elective EVAR has replaced OAR as the more common method of repair in the United States. The introduction of this technology has been rapidly adopted, particularly for the oldest-old surgical patients, aged ≥85 years, who previously may not have been offered surgical intervention for asymptomatic AAA. Further investigation is necessary to examine whether this trend improves the long-term survival and quality of life for this elderly population. (J Vasc Surg 2009;50:722-9.)**

The goal of abdominal aortic aneurysm (AAA) repair is to prevent aneurysm rupture, which has a mortality rate as high as 80% and is responsible for 9000 deaths each year in the United States.[1,2] To this end, patients with asymptomatic AAAs are now typically offered two surgical options: open aneurysm repair (OAR) or endovascular repair (EVAR). For more than 50 years, OAR has been the standard of care. However, since its introduction in the early 1990s, EVAR has rapidly gained popularity.

Although long-term trials of EVAR versus OAR have yet to show a difference in long-term survival between the two procedures, short-term data clearly show an advantage with endovascular stent grafting.[3,4] Adoption of this new technology has been rapid due to the significantly lower risk profile. It is unknown whether diffusion of this technologic advance has gone beyond the previous clinical boundaries for OAR. In the past, these boundaries were commonly restricted by the patient's ability to withstand the physical demands of an open procedure as opposed to the presence of aneurysmal disease.

Historically, advances in technology are first applied to the most robust patients who are most likely to tolerate them.[5] New technology, however, is subject to therapeutic expansion, whereby application of innovative therapy is extended beyond traditional boundaries to additional patients who may not have benefited from standard therapy given the associated risk/benefit ratio.[6] One example of this phenomenon is the adoption of laparoscopic cholecystectomy.[7] Initially, a substantial savings in medical costs due to a decrease in postoperative hospital and recovery expenditures was predicted. In reality, the introduction of laparoscopic cholecystectomy increased the overall costs of cholelithiasis by driving an expansion of the indications for the treatment of biliary disease to a previously untreated group of patients.

The decision to repair an asymptomatic AAA is not necessarily straightforward or solely based on aneurysm size. Patient age appears to be an important factor in the clinical decision-making process[8,9]; however, data about

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age-specific outcomes for elective AAA repair are sparse.[10-12] Furthermore, age-related data may be influenced by the recent rapid diffusion of the use of EVAR. To examine this issue in detail, we used a large administrative database, the National Inpatient Sample (NIS), to quantify, compare, and characterize the national utilization and operative outcomes by age for OAR vs EVAR.

MATERIALS AND METHODS

Data source. The Nationwide Inpatient Sample (NIS) is an annual database of hospital inpatient admissions that is commonly used to identify national trends in health care utilization and outcomes. It is a component of the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality.[13] NIS, a stratified yearly sample of approximately 5 to 8 million hospital stays from nearly 1000 hospitals, is the largest publicly available all-payer inpatient care database in the United States, representing approximately 20% of hospitals, including specialty, community and public hospitals, and academic medical centers.[12]

Data records are patient-level clinical information included in a typical hospital discharge abstract such as demographics, diagnosis (principal and multiple secondary), procedures (principal and multiple secondary), charges, length of stay, and outcomes at discharge. The database also contains hospital data from the American Hospital Association Annual Survey of Hospitals, which includes characteristics such as hospital location (rural vs urban), geographic region, number of beds (small, medium, large), and teaching status.

The NIS is distinct from the CMS Medicare claims database in its ability to capture additional patients, including those aged <64 years. Inpatient care for all-payment sources, including the uninsured and Medicare patients enrolled in HMOs, are also included in the NIS.

We include NIS data from 2001 to 2006 because the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes specific to endovascular aortic repair were not available until October 2000. Data from 2006 were the most recent available from the NIS. United States population data, obtained through the Census Bureau's Web site (www.census.gov), were used to adjust for the population change during the study period.

Data classification. We include all discharges with an ICD-9-CM principal diagnosis code for intact AAA (441.4) and primary procedure codes (39.71); endovascular repair of AAA with graft and resection of abdominal aorta with replacement (38.44).[14] For the purpose of homogeneity, we excluded from the analysis patients aged <50 years and those with secondary diagnostic codes for ruptured AAA (441.3, 441.5), aortic dissection (441.0), thoracic or thoracoabdominal aortic aneurysm (441.1, 441.2, 441.6, 441.7), coarctation of the aorta (747.1), Marfan syndrome and other congenital anomalies (759.8), gonadal dysgenesis-Turner syndrome (758.6), and polyarteritis nodosa (446.0).[15] Only patients with elective admissions were included in the analysis.

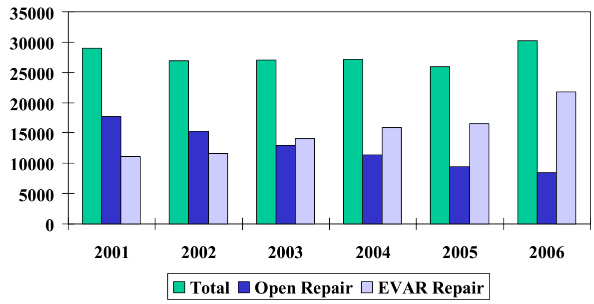

Fig 1. Annual estimates of number of discharges for endovascular and open repairs from 2001 to 2006.

Covariates. We used results of a literature review of ICD-9-CM codes for complications[16-18] to compile a list of codes specifically designed for surgical complications (starting with 996-999) and codes indicating acute conditions complicating surgical operations such as acute myocardial infarction (Appendix I, online only). Codes were grouped as cardiovascular, pulmonary, peripheral vascular, acute renal failure, infection, postoperative shock, bleeding, and wound complications. We also used secondary diagnoses[9,19] to assess the comorbidities of coronary artery diseases, cerebral vascular disease, peripheral vascular disease, chronic obstructive pulmonary disease (COPD), diabetes, and chronic renal insufficiency (Appendix II, online only).

To control for the influence of hospital characteristics on short-term surgical outcomes in our multivariate regression models, we used the NIS variables of hospital location (rural vs urban), teaching status, and number of beds (small, medium, or large). We calculated the total volume of AAA repair procedures at each hospital. We derived hospital volume of OAR or EVAR by counting the total number of discharges with primary or secondary procedure codes of 38.44 (OAR) or 39.71 (EVAR) for each hospital in each given year. Because the measure of hospital volume was positively skewed, a logarithmic transformation was used when the variable of hospital surgical volume was used in regression models.

Statistical analysis. We estimated utilization rates of OAR and EVAR. Given that NIS is a stratified random sample, these estimates were calculated using the sampling strata and weights provided by the HCUP. Weighted least-squares regressions were used to assess population trends from 2001 through 2006.[20]

Early postoperative outcomes include length of hospital stay, in-hospital mortality rate, the proportion of discharges to home versus total discharges, and in-hospital complications. Mortality and complication rates were computed as the estimated number of each event divided by the estimated number of procedures performed during the study period. Multivariate linear regression was used to examine the risk-adjusted association between the type of

Table I. Utilization trend of endovascular and open repairs from 2001 to 2006

Type of repair	*Year* 2001	2002	2003	2004	2005	2006	*Change %*	P
Endovascular								
Age group								
All ages								
Discharges, No.	11171	11579	14068	15857	16525	21725	94	.003
Per capita[a]	14	14	17	19	19	24	71	.004
≥1 comorbidity, %	72.0	73.1	72.9	74.2	75.7	76.8		.001
50-64 y								
Discharges, No.	1562	1482	1908	2057	2411	3363	115	.009
Per capita[a]	4	3	4	4	5	6	50	.009
≥1 comorbidity, %	70.9	69.7	74.0	71.1	74.0	74.7		.071
65-74 y								
Discharges, No.	4467	4490	5333	5908	5980	7851	76	.008
Per capita[a]	24	25	29	32	32	42	75	.008
≥1 comorbidity, %	74.5	75.7	74.1	76.6	77.8	77.9		.022
75-84 y								
Discharges, No.	4452	4765	5755	6623	6755	8703	95	.002
Per capita[a]	35	37	45	51	52	67	91	.002
≥1 comorbidity, %	72.3	72.6	72.0	74.3	75.4	77.6		.007
≥85 y								
Discharges, No.	691	841	1072	1270	1378	1808	162	<.001
Per capita[a]	16	18	23	26	27	34	113	<.001
≥1 comorbidity, %	55.4	67.6	69.3	67.3	70.7	72.4		.050
Open								
Age group								
All ages								
Discharges, No.	17784	15323	12921	11359	9384	8451	–52	<.001
Per capita[a]	23	19	16	13	11	9	–61	<.001
≥1 comorbidity, %	72.8	71.5	73.4	74.8	73.9	79.1		.038
50-64 y								
Discharges, No.	3103	2579	2354	2257	1988	1786	–42	<.001
Per capita[a]	7	6	5	5	4	3	–57	<.001
≥1 comorbidity, %	67.6	68.9	70.8	73.8	70.6	75.0		.016
65-74 y								
Discharges, No.	8062	6572	5550	4695	3743	3537	–56	.001
Per capita[a]	44	36	30	25	20	19	–57	.001
≥1 comorbidity, %	75.4	73.7	75.9	76.2	77.4	81.5		.038
75-84 y								
Discharges, No.	6082	5664	4595	4055	3385	2867	–53	<.001
Per capita[a]	48	44	36	31	26	22	–54	<.001
≥1 comorbidity, %	73.0	71.0	72.7	74.7	73.5	80.1		<.001
≥85 y								
Discharges, No.	536	508	422	353	268	261	–51	<.001
Per capita[a]	12	11	9	7	5	5	–58	<.001
≥1 comorbidity, %	61.8	62.6	64.0	63.5	55.7	63.0		0.710

[a]Discharges per 100,000.

procedure and length of stay. To assess the risk-adjusted effect of the procedure performed (EVAR vs OAR) on in-hospital mortality, rate of discharge to home, and the occurrence of complications, we used multivariate logistic regression analyses. All models were adjusted for patient comorbidities, gender, ZIP-code of residence as a proxy for income, and hospital characteristics (location, number of beds, teaching status, and the logarithmic transformation of hospital surgical volume), and the year the operative procedure was performed. Statistical significance for predictor coefficients was defined as $P < .05$. Statistical analyses were performed using SAS 9.1.3 software (SAS Institute Inc, Cary, NC).

RESULTS

Utilization analysis. The trend for elective AAA repairs in the United States between 2001 and 2006 is shown in Fig 1. In 2001 the estimated number of procedures was 17,784 for OAR and 11,171 for EVAR that met our study criteria for elective operation performed on patients aged ≥50 years for AAA (Table I). In 2006 the estimated number of OAR for intact AAAs decreased to 8451 and the estimated number of EVARs increased to 21,725 (Table I). After adjusting for national population changes during the same period, these operations reflect a per capita decrease of 61% ($P < .001$) for OAR and a

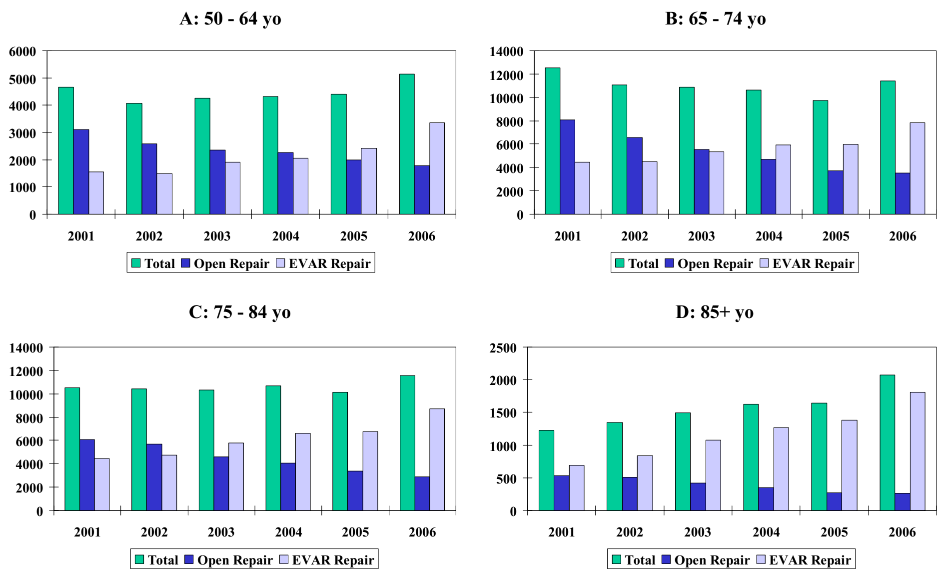

Fig 2. Annual estimates of number of discharges of endovascular and open repairs from 2001 to 2006 by age group **(A)** 50 to 64 years, **(B)** 65 to 74 years, **(C)** 75 to 84 years; and **(D)** ≥85 years.

per capita increase of 71% (P = .003) for EVAR during the 6 years studied.

Fig 2 shows the estimated number of AAA procedures performed, stratified by age group. For each age group, there is a reduction in the number of OARs performed associated with an increase in the number of EVARs performed from 2001 to 2006; however, the shift to EVAR is less pronounced for younger patients aged 50 to 64 years. Strikingly, the number of EVARs for patients aged ≥85 years increased 162% in this 6-year period (Table I). This translates to an increase in the total number of AAA repairs for this oldest group of patients by 69%.

Short-term operative outcomes. From 2001 to 2006, the mean length of stay was 2.67 to 3.30 days for EVAR and 8.33 to 9.01 days for OAR (Table II). In-hospital mortality was 0.64% to 1.23% for EVAR and 3.19% to 4.24% for OAR. Among patients who were discharged alive, 94.4% to 95.0% were discharged to home after undergoing elective EVAR and 82.8% to 86.7% were discharged to home after undergoing elective OAR. During hospitalization, at least one of the complications we examined occurred in 10.95% to 14.6% of patients undergoing EVAR and in 32.0% to 40.0% of patients undergoing OAR (Table II).

Data from all 5 years were pooled to determine the age-specific short-term operative outcomes (Table III). Compared with the elderly, younger patients had a shorter length of hospital stay, a higher proportion of routine discharge to home, and fewer rates of in-hospital death and complications. The in-hospital mortality rate was 0.3%, 0.8%, 1.0%, and 1.5% for patients aged 50 to 64, 65 to 74, 75 to 84, and ≥85 years who had elective EVAR compared with 1.2%, 2.5%, 5.6%, and 9.5% for patients who had elective OAR. Among patients who were discharged alive, >85% were discharged to home in each age group after elective EVAR. Although the rate of routine discharge after OAR was comparable with EVAR in patients aged 50 to 64 and 65 to 74 years, the rate of routine discharge for older patients was much lower, at 71.5% for patients aged 75 to 84 years and 40.2% for patients aged ≥85 years.

Similarly, fewer complications occurred in patients during hospitalization for elective EVAR than in those hospitalized for elective OAR, and this was most pronounced in the elderly. Notably, patients aged 75 to 84 and patients aged ≥85 years undergoing OAR had a >10% risk of cardiovascular complications, pulmonary complications, and acute renal failure, compared with a <5% risk of complications in patients of similar age undergoing EVAR.

After adjusting for patient-specific covariates, including gender, income level, insurance status, comorbidities, and hospital-specific covariates including location, size, teaching status, and surgical volume, we found that patients who had elective EVAR had significantly better early outcomes than patients who had elective OAR overall and for each age group (Table IV). For example, adjusted mean length of stay was 2.5, 2.84, 3.19, and 3.54 days for patients undergoing elective EVAR in our defined age groups of 50 to 64, 65 to 74, 75 to 84, and ≥85 years, respectively, compared with 7.3, 8.2, 9.52, and 9.91 days for patients undergoing elective OAR. The magnitude of the benefit offered by EVAR appears to increase with advancing age. For example, the adjusted odds ratio (OR) of EVAR versus OAR for routine discharge was 5.17 in patients aged ≥85 years compared with 3.95 in those aged 50 to 64 years.

Similarly, patients in the older age groups had greater benefit from EVAR in terms of in-hospital death, cardiovascular complications, pulmonary complications, and acute renal failure than the younger cohort. EVAR had an

Table II. Outcomes of endovascular repair and open repair for all ages

Type of repair	*Year* 2001	2002	2003	2004	2005	2006
Endovascular						
Hospital LOS, mean d	3.30	3.30	3.07	2.88	3.06	2.67
In-hospital mortality, %	1.02	0.92	0.77	0.72	1.23	0.64
Discharge to home, %	94.79	94.77	95.03	94.72	94.40	94.80
Complications, %	14.33	14.44	14.60	13.06	13.25	10.95
Cardiovascular	3.51	3.13	3.75	2.97	3.33	2.41
Pulmonary	3.58	3.80	3.14	2.99	3.85	2.48
Acute renal failure	2.59	2.05	2.02	2.15	2.74	2.40
Infection	0.71	0.71	0.81	0.61	1.00	0.48
Postoperative shock	0.13	0.04	0.10	0.03	0.09	0.24
Bleeding	7.35	7.40	7.97	7.31	6.04	5.45
Wound	0.23	0.08	0.20	0.12	0.12	0.08
Open						
Hospital LOS, mean, d	8.33	8.55	8.46	8.46	9.01	8.78
In-hospital mortality, %	3.19	3.49	3.74	3.41	4.24	3.59
Discharge to home, %	86.72	85.44	85.41	83.21	82.84	82.67
Complications, %	32.02	33.74	37.03	36.78	39.64	39.57
Cardiovascular	8.85	8.80	9.68	7.57	8.54	8.91
Pulmonary	15.21	16.45	17.81	17.50	20.84	19.81
Acute renal failure	5.74	7.41	7.98	9.11	9.61	11.08
Infection	2.34	3.14	2.60	3.64	3.82	4.54
Postoperative shock	0.49	0.38	0.67	0.54	1.35	1.23
Bleeding	11.04	12.24	13.86	13.70	13.57	13.70
Wound	0.95	1.09	1.42	0.98	1.28	0.94

LOS, Length of stay.

Table III. Age-specific outcomes of endovascular and open repairs

	50-64 y		*65-74 y*		*75-84 y*		*≥85 y*	
Outcomes	*EVAR*	*OAR*	*EVAR*	*OAR*	*EVAR*	*OAR*	*EVAR*	*OAR*
Hospital LOS, mean, d	2.5	7.3	2.9	8.2	3.2	9.5	3.5	9.9
In-hospital mortality, %	0.3	1.2	0.8	2.5	1.0	5.6	1.5	9.5
Discharge to home, %	98.1	94.9	96.1	88.0	92.3	71.5	85.6	50.2
≥1 complications, %	8.8	27.3	11.0	34.1	15.7	41.0	17.9	48.9
Complication								
Cardiovascular	1.9	6.3	2.7	7.6	3.7	10.9	4.2	13.9
Pulmonary	2.3	12.8	3.3	16.5	3.5	20.4	3.1	25.3
Acute renal failure	1.3	4.8	1.8	7.3	3.0	10.4	3.0	11.7
Infection	0.5	2.7	0.6	2.6	0.9	3.9	0.6	5.5
Postoperative shock	0.0	0.4	0.1	0.6	0.1	0.9	0.2	1.3
Bleeding	4.3	9.2	5.0	12.4	8.3	14.6	11.2	17.9
Wound	0.2	0.9	0.2	1.2	0.1	1.2	0.0	0.9

EVAR, Endovascular aneurysm repair; *LOS,* length of stay; *OAR,* open aneurysm repair.

advantage for bleeding complications, but this benefit was not more pronounced for those of advanced age; OR of EVAR versus OAR were 0.47, 0.40, 0.59, and 0.61 for patients aged 50 to 64, 65 to 74, 75 to 84, and ≥85 years, respectively.

DISCUSSION

The outcomes of endovascular techniques for repair of AAAs have been a focus of intense research since the introduction of this new technology. Initially, device-specific clinical trials comparing EVAR and OAR reported comparable mortality rates between these two procedures.[21-24] Concurrently, retrospective reviews demonstrated a short-term operative mortality advantage of EVAR.[7,9,11,25] For example, 2003 data from the New York State discharge database demonstrated an operative mortality for elective AAA of 0.8% for EVAR and 4.2% for OAR.[26] Our study, using the most recent years of the NIS, confirms these short-term advantages offered by EVAR.

Given its observational nature, our study may reflect bias in that only anatomically suitable infrarenal AAAs were approached with EVAR, leaving the more anatomically challenging aneurysms for OAR. However, our findings are remarkably similar to the 30-day mortality of 1.2% for

Table IV. Risk-adjusted length of stay, in-hospital mortality, disposition and complication

Complication	Risk-adjusted OR (95% CI)	
	For LOS	P
LOS d		
All ages	EVAR: 2.99 (2.97-3.01) OAR: 8.55 (8.53-8.57)	<.001
50-64 y	EVAR: 2.50 (2.47-2.54) OAR: 7.30 (7.26-7.33)	<.001
65-74 y	EVAR: 2.84 (2.82-2.87) OAR: 8.20 (8.17-8.22)	<.001
75-84 y	EVAR: 3.19 (3.16-3.21) OAR: 9.52 (9.49-9.55)	<.001
≥85 y	EVAR: 3.54 (3.48-3.61) OAR: 9.91 (9.82-10.02)	<.001
	For EVAR vs OAR	
In-hospital mortality		
All ages	0.23 (0.19-0.28)	<.001
50-64 y	0.25 (0.11-0.58)	.001
65-74 y	0.37 (0.27-0.52)	<.001
75-84 y	0.20 (0.15-0.26)	<.001
≥85 y	0.18 (0.10-0.31)	<.001
Disposition to home		
All ages	3.95 (3.62-4.31)	<.001
50-64 y	2.51 (1.73-3.66)	<.001
65-74 y	3.00 (2.55-3.54)	<.001
75-84 y	4.24 (3.77-4.76)	<.001
≥85 y	5.17 (3.95-6.75)	<.001
Complications		
Any		
All ages	0.27 (0.25-0.28)	<.001
50-64 y	0.27 (0.23-0.32)	<.001
65-74 y	0.25 (0.23-0.28)	<.001
75-84 y	0.29 (0.27-0.32)	<.001
≥85 y	0.23 (0.18-0.29)	<.001
Cardiovascular		
All ages	0.33 (0.30-0.37)	<.001
50-64 y	0.31 (0.23-0.43)	<.001
65-74 y	0.36 (0.30-0.43)	<.001
75-84 y	0.33 (0.28-0.39)	<.001
≥85 y	0.27 (0.18-0.40)	<.001
Pulmonary		
All ages	0.16 (0.15-0.18)	<.001
50-64 y	0.17 (0.13-0.23)	<.001
65-74 y	0.21 (0.18-0.24)	<.001
75-84 y	0.15 (0.13-0.18)	<.001
≥85 y	0.09 (0.06-0.13)	<.001
Acute renal failure		
All ages	0.24 (0.21-0.27)	<.001
50-64 y	0.27 (0.18-0.41)	<.001
65-74 y	0.23 (0.18-0.28)	<.001
75-84 y	0.26 (0.22-0.31)	<.001
≥85 y	0.18 (0.11-0.30)	<.001
Bleeding		
All ages	0.50 (0.46-0.54)	<.001
50-64 y	0.47 (0.37-0.59)	<.001
65-74 y	0.40 (0.34-0.45)	<.001
75-84 y	0.59 (0.53-0.67)	<.001
≥85 y	0.61 (0.45-0.82)	.001

CI, Confidence interval; *EVAR,* endovascular aneurysm repair; *LOS,* length of stay; *OAR,* open aneurysm repair; *OR,* odds ratio.

EVAR and 4.7% for OAR observed in the Dutch Randomised Endovascular Aneurysm Management (DREAM) trial, which compared these two procedures in patients who were candidates for both repairs.[3]

We found additional advantages of EVAR in terms of major complications, length of stay, and proportion of routine discharge that affirms a substantial reduction in the immediate postoperative risks provided by this approach. Although the advantage of EVAR for perioperative surgical outcomes is evident for every age group, this advantage is most pronounced for patients with advancing age. For example, for patients aged ≥85 years, the in-hospital mortality rate for OAR was more than five times that for EVAR. Furthermore, among those who were discharged alive in this oldest-old group, only 50% were discharged to home after OAR, whereas >85% were routinely discharged to home after EVAR. Pulmonary, cardiovascular, and renal complications were also dramatically reduced for these elderly patients who had EVAR.

It is important to note two distinct and recent publications using the Medicare claims database from 2001 to 2003.[11,27] Both studies showed similar results with respect to short-term EVAR outcomes for elderly patients, analogous to our study, which used the NIS database. This study extends these findings about EVAR utilization past 2003, which the NIS analysis indicates was the fulcrum at which the use of EVAR exceeded OAR for elective AAA repair. Interestingly, we have shown a perpetuation of that trend, whereby preference for EVAR continued to increase and accounted for 71.9% of AAA repairs in 2006.

It is notable that this shift is most dramatic for patients aged >85 years. Although the combined utilization of OAR and EVAR for intact AAAs remained stable or declined in all other age groups, patients aged ≥85 years saw a substantial increase in the performance of any AAA repair from 2001 to 2006. The expansion of the pool of candidates for AAA surgery can be explained by the reduced short-term risk profile provided by EVAR, which has offered physicians and patients a more palatable choice for intervention, pushing overall operative rates higher.

Although EVAR certainly confers a short-term survival advantage for this older group compared with OAR, we cannot determine whether a long-term survival advantage was achieved for this group compared with a noninterventional choice. Certainly, existing data from two large randomized controlled trials comparing repair types demonstrate loss of this short-term survival advantage after only 2 years of follow-up, but these studies did not stratify patients by age.[3,4] Furthermore, no survival advantage (from all causes) from EVAR versus nonintervention was demonstrated at 4 years for nonoperative candidates, and these patients were a mean age of 76.[28]

Given advanced age and higher prevalence of comorbidities, the survival advantage from either OAR or EVAR may be limited in patients aged >85 years. One case series that examined this question found no long-term survival advantage for EVAR versus OAR for patients aged ≥80 years.[29] Furthermore, this case series demonstrated that this population of patients who underwent AAA repair by either method had a significantly higher mortality rate over time than the general population of patients aged >80 years. [30] Given the rapid diffusion of this new technology into a previously untreated group of patients with AAA primarily created by the introduction of EVAR for patients ages ≥85 that is shown here, the question of long-term survival and freedom from aneurysm-related death require further investigation.

Surgical management with EVAR may offer other advantages to these elderly patients beyond improved survival and freedom from aneurysm-related death. Freedom from anxiety and fear of AAA rupture[31,32] may now be worth the risk of AAA repair for these elderly patients given the dramatically improved risk profile and the likelihood of home discharge for most of them. In addition, there is a well documented cohort of patients aged >80 years who have a relatively long life expectancy,[26] and the mortality benefit for this group conferred by EVAR may be significant. Unfortunately, the prevalence of aneurysmal disease in this oldest-old group is currently unknown.

This study has some limitations. The NIS does not contain data from all 50 states and may not represent the population of all the hospitals within the states where the data were collected, leaving our results subject to sample bias. Our analysis is also limited by the completeness and accuracy of coding. Discrete end points such as in-hospital death are generally accurate, but preoperative comorbidities and in-hospital complications are subject to interpretation and bias. Most importantly, we are limited by the variables available in the database. We could not assess the severity of the comorbidities or the complications, nor were there any records for the size of the AAAs.

Even given the limitations of the NIS database, however, we believe it is a valuable resource to assess broad trends in the nation and estimate immediate surgical outcomes including death from AAA repair. The large volume of data collected over years from multiple tiers of hospitals gives this database an advantage relative to smaller individual case series that generally reflect experience of a single institution or surgeon.

CONCLUSIONS

This study provides outcome analysis on elective AAA repairs from a population perspective. We found that short-term surgical outcomes are consistently favorable for EVAR, and thus endovascular techniques have replaced open repair as the more common operation for elective AAA repair. Older patients receive the largest advantage from the surgical risk-reduction offered by EVAR, which likely explains the dramatic increase in the total number of patients aged ≥85 years undergoing AAA repair, primarily using EVAR. Further investigation is necessary to determine whether this expansion of the indications for AAA repair created by the introduction new technology improves long-term survival, freedom from aneurysm-related mortality and quality of life.

AUTHOR CONTRIBUTIONS

Conception and design: MS, YS, WD
Analysis and interpretation: MS, YS, JH, WD
Data collection: YS
Writing the article: MS, YS
Critical revision of the article: MS
Final approval of the article: MS, WD
Statistical analysis: YS, JH
Obtained funding: YS, WD
Overall responsibility: MS

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Additional material for this article may be found online at www.jvascsurg.org.

Appendix I (online only). List of ICD-9-CM codes for comorbidities[16,18]

Comorbidities	*ICD-9-CM codes*
Coronary	
Old myocardial infarction	412
Coronary atherosclerosis	414.0
Aneurysm and dissection of heart	414.1
Other specified or unspecified chronic ischemic heart disease	414.8, 414.9
Hypertensive heart disease	402
Unspecified cardiovascular disease	429.2
Cerebral	
Occlusion and stenosis of precerebral arteries	433
Occlusion of cerebral arteries	434
Other and ill-defined cerebrovascular disease	437
Late effect of cerebrovascular disease[a]	438
Peripheral vascular disease	
Atherosclerosis	440
Unspecified peripheral vascular disease	443.9
Chronic obstructive pulmonary disease	
Chronic bronchitis	491
Emphysema	492
Asthma	493
Bronchiectasis	494
Chronic airway obstruction, not elsewhere specified	496
Pneumoconiosis	500-505
Chronic respiratory conditions due to fumes and vapors	506.4
Diabetes	
Diabetes mellitus	250
Chronic renal insufficiency	
Hypertensive renal disease	403
Chronic glomerulonephritis	582
Chronic renal failure	585

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.
[a]Excluding cases with concurrent codes of 430, 431, 432, 435, or 436.

Appendix II (online only). ICD-9-CM codes of complications[15-17]

Complications	*ICD-9-CM codes*
Cardiovascular complications	
Cardiac arrest/insufficiency; heart failure during or resulting from a procedure	997.1
Acute myocardial infarction	410.0-410.9
Postoperative stroke	997.02
Postoperative deep venous thrombosis	997.79
Postoperative pulmonary embolism	415.11
Phlebitis or thrombophlebitis from procedure	997.2
Pulmonary complications	
Mendelson syndrome or pneumonia resulting from a procedure	997.3
Acute respiratory failure	518.81
Postoperative acute respiratory insufficiency	518.5
Postoperative pulmonary edema, or acute pulmonary edema	518.4
Postoperative pneumothorax	512.1
Acute renal failure	584.5-584.9
Infection	
Postoperative infection	998.5, 998.51, 998.59
Infection and inflammatory reaction due to other vascular device, implant, and graft (arterial graft, arteriovenous fistula or shunt, infusion pump, vascular catheter)	996.62
Severe sepsis	995.92
Septicemia	038.0-038.9
Septic shock	785.52
Postoperative shock	998.0
Bleeding	
Acute posthemorrhagic anemia (anemia due to acute blood loss)	285.1
Hemorrhage or hematoma or seroma complicating a procedure	998.1, 998.11, 998.12, 998.13
Wound complications	
Delayed wound healing	998.83
Disruption of operative wound	998.3
Persistent postoperative fistula	998.6

ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.